PASS II AND RUNTIME ROUTINES OF IITPL COMPILER

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for the Degree of
MASTER OF TECHNOLOGY

BY
MUKUL KUMAR SINHA

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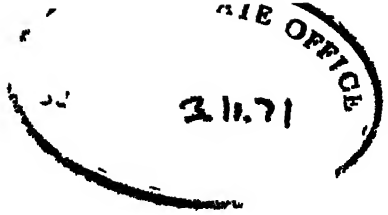

CERTIFICATE

Certified that this work on "Pass II and Runtime Routines of IIIPL Compiler" has been carried out under my supervision and that this has not been submitted elsewhere for a degree.

Dr. H.N. Mahabala
Associate Professor
Department of Electrical Engineering
Indian Institute of Technology
Kanpur

ACKNOWLEDGEMENT

I would like to express my gratitude to Dr. H.N. Mahabala, the supervisor of the project, for his inspiring and valuable guidance.

My special thanks are due to Sri J.K. Sinha, the co-worker of the project who showed his untiring effort and extended his full help for the completion of the project.

But the final achievement still remained a mirage due to the system trouble (specially in DISK) which stood in the way continuously for the last two months.

Finally thanks are also due to Sri K.N.Tewari for his excellent typing.

M.K. Sinha

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SYNOPSIS

This project work has been done for the implementation of IITPL, a language suitable for system implementation, on IBM 7044. This compiler is an out-core type, comprising of two passes. Present work elaborates the working of Pass II (of the compiler) and Runtime Routines (used during execution).

The output of Pass II, the final coding in MAP of a IITPL source programme is loaded to the assembler, the output of which, inturn with runtime routines, is fed as input to the loader for the execution of the programme.

The programme is written in FORTRAN IV with runtime routines in MAP, the assembly language of IBM 7044.

CHAPTER I

INTRODUCTION

The purpose of the project "Implementation of IITPL on IBM 7044" is to select and implement a language suitable for system implementation.

This project work has been carried out jointly by the author and Mr. J.K. Sinha. Present thesis deals with the second part (last part) of the project. To understand the complete picture of the project, one is suggested to go through the thesis presented by Mr. J.K. Sinha.

In this part, the descriptions of the Intermediate Processor (which manages the provisions for subprogramme linkage and checks validity of inter-subprogramme control transfers), the coding done in PASS II, management of dynamic allocation, and runtime routines are given.

In PASS I of the compiler (See Appendix I) coding of all statements, except CALL statements and those GOTO statements, the coding of which is not possible in PASS I, is done. To facilitate the coding of CALL and above mentioned GOTO statements in PASS II; symbol table, ICALL table, and GOTO table are managed by PASS I (See Appendix II).

Symbol Table: It is a table of all the labels, variables declared in the subprogramme and block names. Particular labels or variables can be searched in symbol table by SYMTAB routine (See Appendix II).

ICALL table . ICALL table keeps all the cross refcrences between blocks.

GOTO Table: It is a table of strings of unfound labels of procedures. The first label of each string is the name of the procedure where rest lables of the strings are needed by GOTO statements.

For keeping the track of the blocks in PASS II, strings are provided by PASS I at coding points of PROCEDURE, BEGIN and END statements.

The PASS I output of the IITPL source program is on TAPE 0, which is taken as input for the PASS II. The final compiled output of the IITPL programme is written on TAPE 4 which is loaded for the execution.

CHAPTER II

INTERMEDIATE PROCESSOR

The functions of Intermediate Processor are the followings:

1) This checks the validity of subprogramme linkage and proper arrangements are done for inter-subprogramme transfer.
2) Possibility of recursion and invalid inter-subprogramme transfer is sensed.

Checking for Recursion:

With the help of ICALL table, the lowest level(L) procedure, called by any procedure is looked out first. If there are many procedures of lowest level (L), then the procedure which is topmost in the ICALL table is taken. Then a string of L level procedures elements with this procedure as HEADER, is formed. Each preceding link (or element) calls the following link. If any particular link (i.e. procedure) is found again, it shows the recursion. Thus is given error. The above mentioned string is formed in ICHECK table.

Similar operation is done, with next procedure of level L as header, until the checking with all the procedures of level L as header is done. Then similar checking is done with the precedures of level (L-1), (L-2),...2 respectively.

In this way all possible recursions are checked.

Provision for Inter-subprogramme Linkage:

In any subprogramme, one or more active blocks can be simultaneously ended by one single GOTO statement. It depends upon the path of activation of blocks and the availability in the active blocks of the label where the control wants to transfer.

Example:

```
P1..PROCEDURE ,.
    CALL P2 ,.
P2..PROCEDURE ,.
L2..Stmt ,.
    BEGIN ,.
    CALL P3 ,.
L3..Stmt ,.
    END P2 ,.
    CALL P3 ,.
P3..PROCEDURE ,.
    GOTO L3 ,.
    Stmts
    GOTO L2 ,.
    Stmts
    GOTO L1 ,.
    END P3 ,.
L1..Stmt ,.
L2..Stmt ,.
L3..Stmt ,.
    END P1 ,.
```

Procedure P3 can be activated in two ways:

1) P3 activated by P1 - In this case, all the three statements 'GOTO L3,' 'GOTO L2,' and 'GOTO L1,' will cause termination of the block P3 and the control will go to the labels L3, L2 and L1 of procedure P1 for the corresponding GOTO statement.

2) P2 activated by P1, which activates BEGIN block, which in turn activates P3:-

Now the three GOTO statements of procedure P3 will adopt three different courses of actions. Each case is discussed below:

i) GOTO L3 - Since L3 is not available in P3, so P3 will be terminated and the control is now in the BEGIN block, which has a statement with label L3 and thus control will transfer to this L3.

ii) GOTO L2 - Since L2 is not available in P3, P3 will be terminated and the control is in BEGIN, where also L2 is not available and so this block will also be terminated and by tracing back the activation path, the control reaches the procedure P2, where L2 is found, thus the control transfers to that statement.

iii) GOTO L1 - Similar to L2, it will reach upto the procedure P2, but since L1 is not available even there, it will also be terminated and the control will transfer to L1 of the procedure P1, as if there were a 'GOTO L1' statement in the procedure P2.

It is quite clear from the previous example that points for the control transfer can only be provided after knowing all the possible paths of activation of blocks. That is why coding of C LL and GOTO (partially) is done in PASS II.

The ICALL table made in PASS I keeps the information of all the possible activations of blocks, which are used by Intermediate processor for providing points for the control transfer.

The Intermediate processor picks out the called procedure (say P) of lowest level (say L) from ICALL Table. If the procedure P is called by several blocks, then the topmost among them is taken. Let it be ICALL(L). Now calling block may be either a Procedure block or a BEGIN block.

Procedure Block: The availability of unfound labels(if any) of "Called Procedure" is checked in the procedure P1 calling it. If any particular label (L1) (or labels) is not found even in the calling procedure (P1) then it is treated as if 'GOTO L1' statement be in P1 and hence the label (L1) is attached to the string of unfound labels of calling procedure (P1) and the corresponding changes are done in GOTO table.

BEGIN Block: Firstly, with the help of symbol table, the path of activation of this BEGIN block is traced, until a PROCEDURE is found. These blocks are kept in

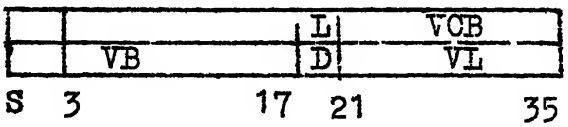
the block stack with assumption that the procedure is a block of level 1.

If the BEGIN block is just under procedure there will be only two blocks in the stack. But if the BEGIN is under some other Begin and that under some other BEGIN.. and that under... and last one under procedure then all the BEGIN blocks and the procedure will be in the block stack.

After arranging such a hypothetical block stack, the availability of each unfound label of "Called Procedure" is chedked.

1) If the label is not found in any of the block (even in the procedure) of the block stack, then it is treated just like the procedure case and the label is attached to the string of unfound labels of the procedure in GOTO table.

2) If label is found in procedure or any BEGIN block of block stack, the following information is kept in GOTO table, which is utilized at the time of coding in PASS II:



VCB - Value of calling BEGIN block

L - Level of calling BEGIN block

VL - Value of Label

VB - Value of BEGIN block where label is found

D - Level difference of calling BEGIN block and the BEGIN block where label is found.

Here 'Value' indicates the symbol table address.

After taking above action for each label of the called procedure, ICALL(L) is made zero.

The above action is taken again with the new ICALL table and this is done until all locations of ICALL table are made zero.

Now the expanded and new GOTO table is the final GOTO table which will be used in PASS II for coding.

CHAPTER III

PASS II

In the PASS II, the PASS I output, which is on the tape 0, is scanned statement by statement. If the first word of the statement is either of the five special characters (discussed below), it shows the presence of a string, for which the corresponding coding is to be done in PASS II.

Those special characters are

Characters	Octal Value	String of
⌐	57	PROCEDURE
\	76	BEGIN
Y	75	CALL
+++	77	GOTO/GO TO
;	56	END

Coding done by the compiler, for different types of strings is discussed below one by one.

1) PROCEDURE String

Example:

PASS I OUTPUT

```
$IBMAP   FGH
FGH      TRA      .I0001
.V0001   SXA      ..IDX2,2
         TSX      .SUBR2,2
```

```
                PZE     3
                PZE     5
                PZE     3
        .I0001  BSS
        | 00000 | | S T A |
                TSL     .RTRTN
```

where T - Type (0 for simple proccdure,
4 for functional proccdurc).

S - Block number of procedure block.

A - Symbol table address of proccdurc name.

In this case, the first eight MAP instructions are transferred in toto to the tape 4. The first word ninth statement, indicates the presence of PROCEDURE s

The word, immediately after special character, keep the symbol table address of the PROCEDURE name (i.e. FGH in this particular case) in its address portion.

On encountering a PROCEDURE string in PASS II, similar to PASS I, the procedure is kept in the Block table.

With the help of the Symbol table address (A), the number of variables declared in the procedure is taken and it replaces the address portion of the second word of the string. Now treating this word as an integer, coding

```
CLA     =Ø000001000017
```

is done and the string is removed.

And the PASS II output will look as follows:

PASS II Output.

```
        $IBMAP   FGH
        FGH      TRA      .I0001
        .V0001   SXA      ..IDX2,2
                 TSX      .SUBR2,2
                 PZE      3
                 PZE      5
                 PZE      3
        .I0001   BSS
                 CLA      =Ø000001000017
                 TSL      .RTRTN
```

2) BEGIN String

Example:

PASS I OUTPUT

```
                 ..       ..
        M        CLA      5,1
                 ADD      2,1
                 STO      5,1
        00000 \  ↑   A
          IBLIO
                 TRA      .I0007
                 ..       ..
```

where A - Symbol table address of BEGIN.

The first word of the above example, indicates the presence of BEGIN string.

On encountering the BEGIN string, similar to PASS I, the BEGIN block is kept in the Block table and the string is removed The PASS II output will look like as follows:

PASS II Output

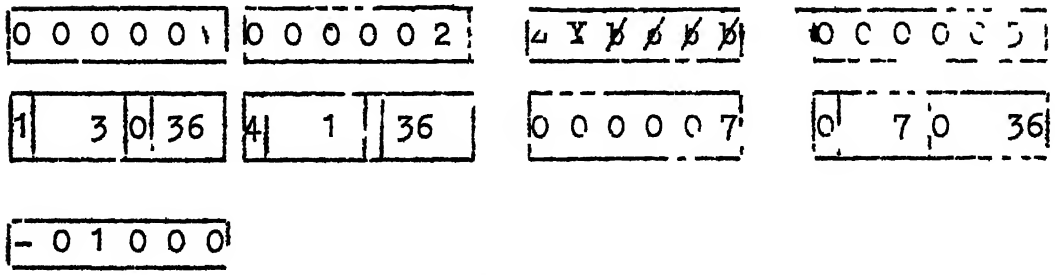
```
                ..      ..
        M       CLA     5,1
                ADD     2,1
                STO     5,1
                TRA     .I0007
                ..      .
```

3) CALL String:

Example of PASS I output string and the expanded GOTO table are shown below.

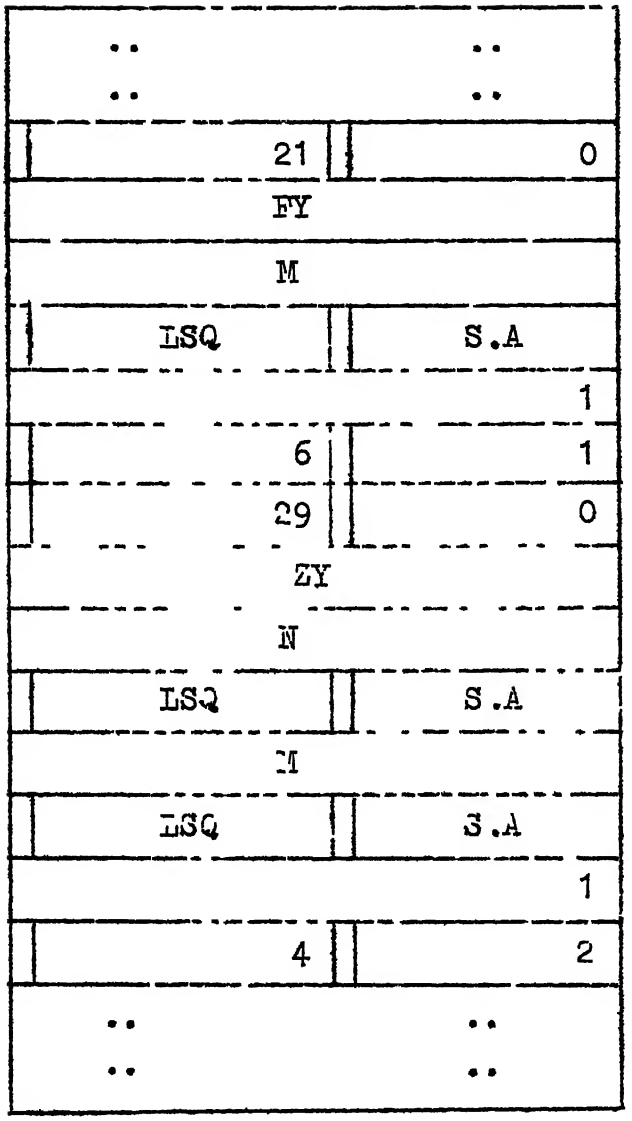
PASS I OUTPUT

```
                ..      ..
        .L0002  CLA*    2,1
                STO*    1,1
```




```
                TRA     .P0010
                ..      ..
```

GOTO table:



for LSQ, S.A see Appendix II.

With the help of these two, coding of CALL string is done. It is also assumed that the CALL statement has appeared in PROCEDURE FY. GOTO table shows that the label 'M' and the label 'N' are not available in procedure 'ZY' and 'M' is also unavailable in 'FY'; which shows that 'N' is the label of any statement in procedure 'FY'.

Now with this CALL statement, return points are to be provided since labels 'II' and 'II' are unavailable in the procedure 'ZY'.

The fourth word of the string shows the number of arguments and the succeeding four words contain the information of the arguments (refer to CALL argument characteristic word in Appendix II).

Since label 'M' is also not available in 'FY' procedure, so transfer is done to a new label calculated as follows:

.C0000+C(ICALL(20))$_{3-17}$+Position of label 'M' in string of the procedure 'FY' (i.e. 1 in this case). The statement, assigned this new label, will terminate the procedure 'FY' and will transfer the control to the upper block. The PASS II Output will look as follows:

PASS II Output

```
.L0002    CLA*    2,1
          STO*    1,1
          TSL     ZY
          TXI     *+6,,3
          PZE     3,1
          PZE     =7
          PZE     7,1
          TRA     N
          TRA     .C0007
          TRA     .P0010
```

4) GOTO String.

Example

PASS I OUTPUT

```
          ..                  ..
                TRA      K
          J     BSS
          000000 000001  Mbbbbb
          K     CLA      1,1
          ..                  .
```

It is assumed that this GOTO string is found in the procedure 'ZY' and the GOTO table of previous example is also true for it.

The label 'M' is searched in PASS II also:

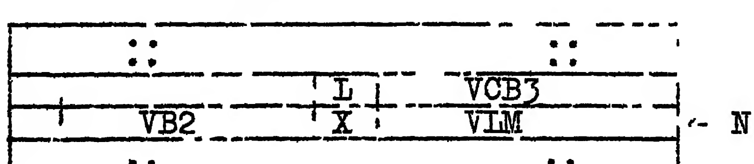
(a) If 'M' is found in the same block, the following coding is done

```
TRA     M
```

(b) If 'M' is not found, it is picked out from GOTO table and its new label is calculated as in the case of the CALL string (i.e. .00006 for 'M' in procedure 'ZY'). And the coding will be:

```
TRA     .00006
```

(c) If GOTO string has come in BEGIN block 'B3' and if COLECT table is as shown below:



where

VCB3 - Symbol table address of BEGIN block'B3'.

VB2 - Symbol table address of block 'B2' where label 'M' is found.

VLM - Symbol table address of the label 'M'.

L - Level of block 'B3'

X - Level difference of blocks 'B3' and 'B2'.

the label 'M' is found in the COLLECT table and the following coding is done:

```
TRA     .RCOOn
```

where 'n' is the location of the label 'M' in the COLLECT table.

5) END String:

Example:

PASS I OUTPUT

```
..              ..
    CLA     3,1
    STO     5,1
    00000;
    CLA     =2
    TSL     .RTRTN
..              ..
```

END string may come either in BEGIN block or in PROCEDURE block.

1) END Corresponding to BEGIN: From the block stack, the symbol table address of BEGIN (VCB) is searched. In COLECT area the presence of VCB as block, which wants label, is checked.

a) If it is there, the coding for all the desired labels are done with the help of their VB, X and VLM (see figure in the previous page). To encompass the set of statements, coding for the labels needed, a transfer instruction is given in the very beginning as:

```
        TRA     .ROOOm
```

and at the end following instruction is generated:

```
    .ROOOm    BSS
```

where 'm' = N-1, N is the COLECT table address of the BEGIN string.

The PASS II output will look as follows:

PASS II Output

```
                ..                      ..
                    CLA     3,1
                    STO     5,1
                    TRA     .ROOOm
            .ROOON  CLS     =iblno
                    TSL     .RTRTN
                    TRA     N
            .ROOOm  BSS
                    CLA     =2
                    TSL     .RTRTN
                ..                      ..
```

where 'iblno' is internal block number of the BEGIN block.

b) If the BEGIN block is not found in the COLECT table then no coding is done. The last block is erased from the block stack and the string is removed.simply.

ii) END Corresponding to PROCEDURE: From the block stack, the symbol table address of the procedure is searched.

a) If the string of unfound labels is attached to the procedure, the coding for all the unfound labels is done similar to the BEGIN case but here GOTO table is taken help of instead of the COLECT table. To encompass the set of instructions, similar statements are generated here also. It is assumed th t the statement "END, " corresponding to the procedure 'FY' has come, then the PASS II output will be as follows

PASS II Output

```
                CLA     3,1
                STO     5,1
                TRA     .G0001
.C0007          CLA     =2
                TSL     .RTRTN
                LXA     FY,4
                SXA     *+1,4
                LXA     **,4
                TIX     *+1,4,1
                SXA     FY,4
                TPA     FY
.G0001          BSS
                CLA     =2
```

Here the encompassing instructions have labels different from that of BEGIN case.

(b) If there is no setting of outward labels attached to this procedure, only block stack entry is created and no coding is done.

If the END statement is corresponding to the last procedure of the subprogramme, the control transfers to the END of the compiler and the PASS II output is now loaded on IBM 7044.

CHAPTER IV

DYNAMIC ALLOCATION RUNTIME ROUTINES

The most beautiful feature of IITPL is that the declared identifiers and global identifiers have dynamic allocations, i.e. to say, identifiers declared in any block occupy the corresponding memory locations, only when, the block is active. As soon as the block ends (either by usual END statement, or by conditional or unconditional transfer to the point which is outside the block, at the time of execution), the allocated memory locations needed for this block are freed which may be used by another block, going to be active next.

Following example illustrates how dynamic allocation functions:

```
A..PROCEDURE OPTIONS (MAIN) ,.
   DECLARE (VA1, VA2, VA3, VA4) FIXED ,.
   Stmts
   CALL B ,.
B..PROCEDURE ,.
   DECLARE (VB1, VB2, VB3) FIXED ,.
   Stmts
   END B ,.
C..BEGIN ,.
   DECLARE (VC1, VC2, VC3, VC4, VC5) FIXED ,.
   Stmts
   END A ,.
```

In the previous example procedure A calls procedure B. Three variables are needed in this block (assuming that no global identifiers are needed in block B). As soon as procedure B is invoked during execution by the CALL statement in procedure A, three locations are allocated for B block and these locations are freed when control transfers back in A block. Furthermore, when control enters into C block (Begin block C), five memory locations will be allocated to C block, three of them will be those which were occupied by B block when it was active.

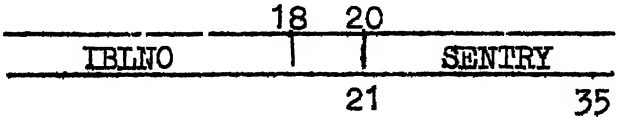
Thus overlapping of memory is done.

In IITPL this type of facility (i.e. dynamic allocation) has been developed with the help of runtime manager of variables (i.e. variable stack) and of active blocks (i.e. active block stack).

The programme has been written in MAP, the assembly language of IBM 7044. Here few names and pointers used in the programme of runtime manager are described:

ACTBLS (Active Block Stack).

This is a variable name which heads the active block stack i.e. ACTBLS is the starting point of active block stack. Each entry in the active block stack occupies only one memory and consists of the following information



where IBLNO is the internal block number given to this block by the compiler to identify any active block during execution.

SENTRY is the starting entry in the variable stack after which data area for this block starts in variable stack.

..VAR points out the starting point of the variable stack formed for the purpose of data allocation. The length of the variable stack depends upon the user's programme which is calculated during compilation for the worst case.

STPTKB works as a pointer and points to the starting point of current active block in variable stack.

NVARKB (Number of Variables in Current Block):

As the name suggests it gives the number of variables (or more accurately number of memory locations) needed by the current active block for data allocation.

To understand the function of the runtime manager and above mentioned names, let us consider the following example:

```
A..PROCEDURE OPTIONS (MAIN) ,.
   DECLARE (VA1,VA2,VA3,VA4,VA5(10)) FIXED ,.
   Stmts
   CALL C ,.
   CALL B ,.
```

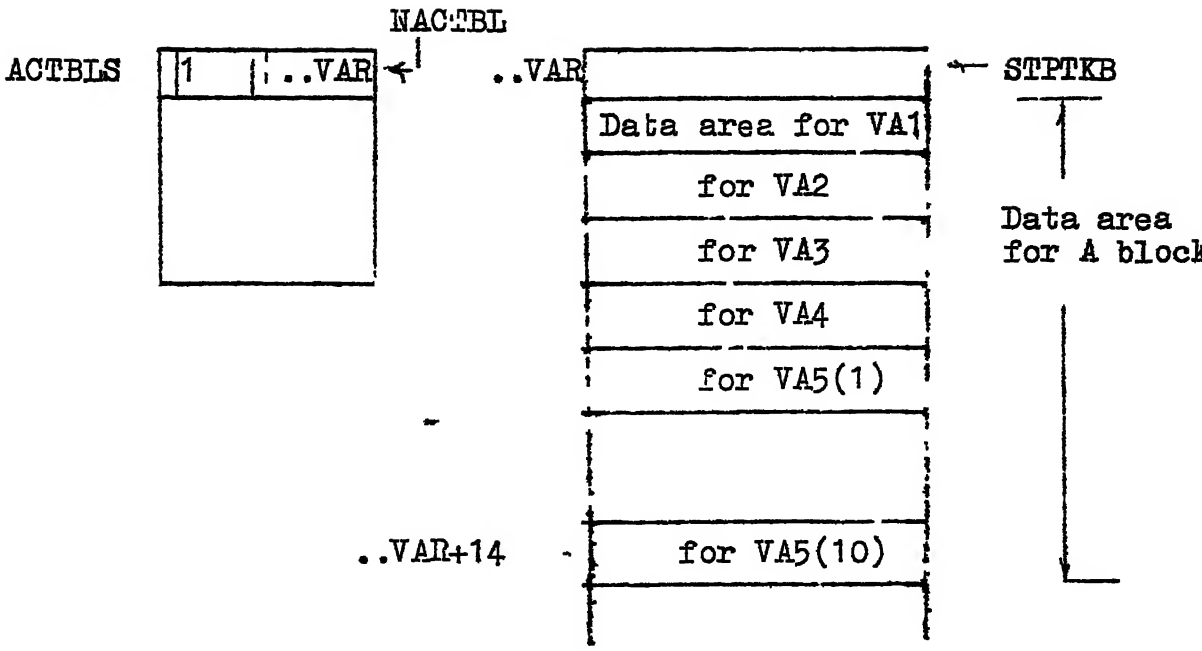
```
B..PROCEDURE ,.
    DECLARE (VB1,VB2,VB3,VB4,VB5)BIT(36) ,.
    Stmts
    VA1=VA5(2)+VA5(3)+VA3+VA4 ,.
    CALL C ,.
BEG1..BEGIN ,.
    DECLARE B1(5,6,7) FIXED ,.
    Stmts
    CALL C ,.
    END A ,.
C..PROCEDURE ,.
    DECLARE (C1) FIXED ,.
    DECLARE (C2,C3,C4,C5) BIT (50) ,.
    Stmts
    END C ,.
```

Initial instructions of any block (i.e. prologue of any block) are those which load the block in active block stack.

Referring to the present example, the prologue of the block A will load the block A in active block stack. Index1 and index2 act as pointers which give information about starting point of data area in variable stack for current active block and previous active block.

As the control enters into A block, the two stacks (active block stack and variable stack) will look like

as follows:



Here 1 in the decrement portion of ACTBLS shows the internal block number of A while address portion of ACTBLS is filled up by ..VAR, an entry in the variable stock just one location before the starting point (..VAR+1 in this case) of the data area for block A.

Pointers will have the values as follows:

NACTBL = 1 showing that number of active blocks is one.

NVARKB =14 showing that number of memory locations needed by this block is 14.

index'1'= complement of ..VAR so that if any identifier is to be referred to,it will be referred to as:

irpn,1

where irpn is internal relative position number.

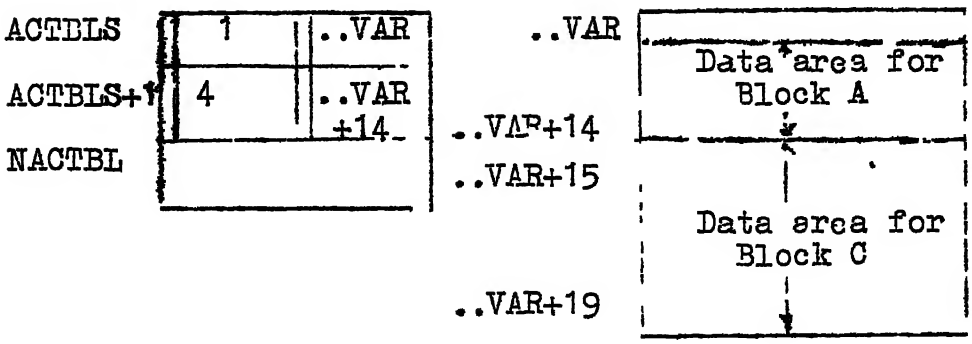
irpn for VA1 = 1

irpn for VA4 = 4

irpn for VA5(7)=11 and so on.

index'2'= 0.

When procedure block C is activated by CALL statement in block A, block C is also loaded and entries of two stacks are:



where 4 is the internal block number for block C.

NACTBL = 2 NVARKB = 5

index 1 = complement of (..VAR+14)

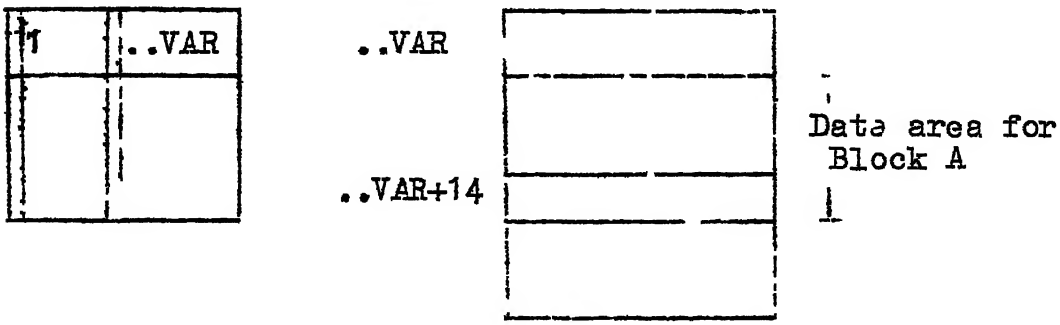
index 2 = complement of (..VAR)

When C block ends, this block is erased from the active block stack and the pointers are moved back accordingly.

Now NACTBL = 1 NVARKB = 14

index 1 = complement of ..VAR

index 2 = 0



Similarly when B block is activated, different pointers will have the following values:

NACTBL = 2 NVARKB = 9

index '1' = complement of (..VAR+14)

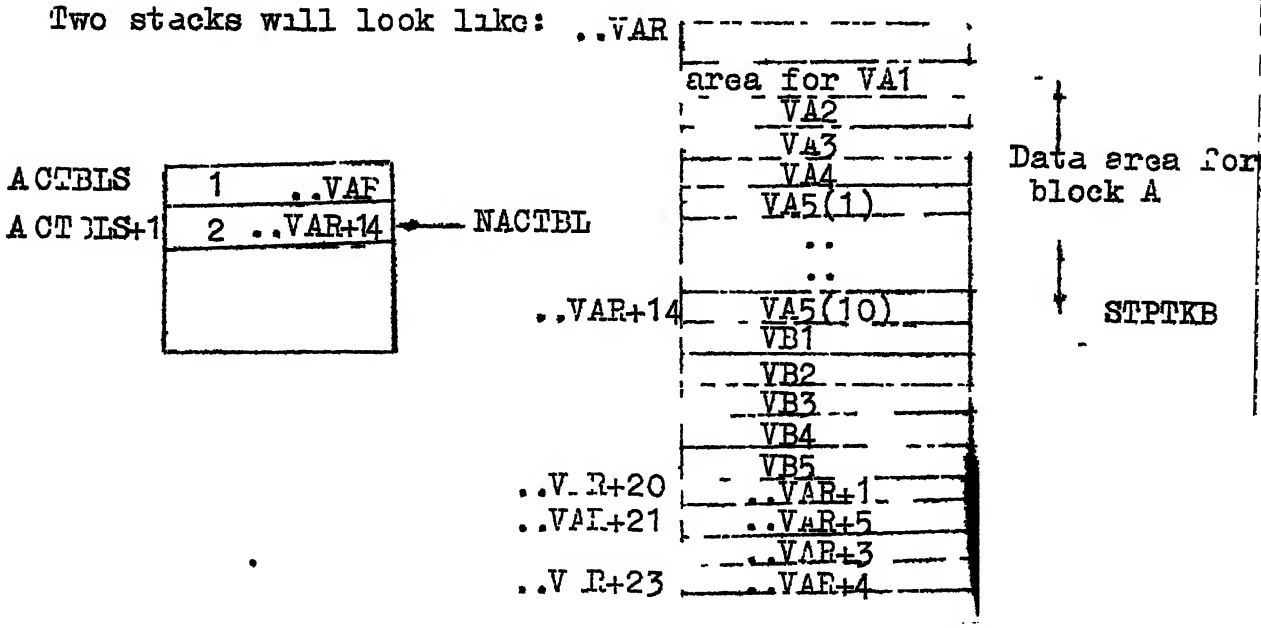
index '2' = complement of (..VAR)

In this case NVARKB = 9, five locations for local identifiers and four for global identifiers (three for VA1,VA3 and VA4 and one for array name VA5).

It can be marked here that VA5 is an array name declared in A block and is needed by B block as global identifiers. Also in A block, ten locations are reserved (VA5(10)) for its allocation in variable stack while only one location is required in B block for the array name also if this array is global.

In this single location for array name, starting point of array name in A block is stored, so that actual address of any element of the array can be evaluated.

Two stacks will look like:



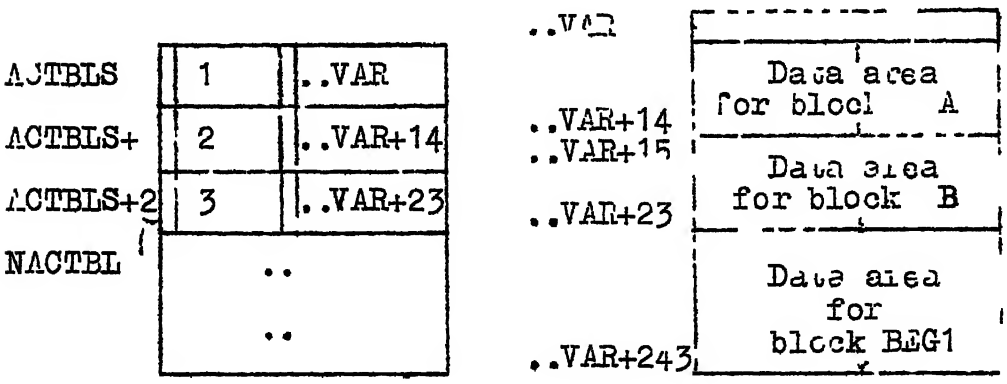
It can be noticed that ..VAR+20 contains the entry point of the identifier VA1 i.e. (..VAR+1). Hence if VA1 is referred in block B, it will be referred to as

OP-CODE' irpn,1

here'irpn'for VA1 in block B is 6.

Hence obviously, the indirect address of (6,1) will refer to the address ..VAR+1 which, in turn, is nothing but the entry for VA1. Similar is the case with the other global identifiers.

Again when control enters into begin block the stacks will be



index '1' = complement of (..VAR+23)

index '2' = complement of (..VAR+14)

When CALL C in begin block BEG1 is executed, control is transferred into C block and all the blocks are active now. The different pointers will have the values:

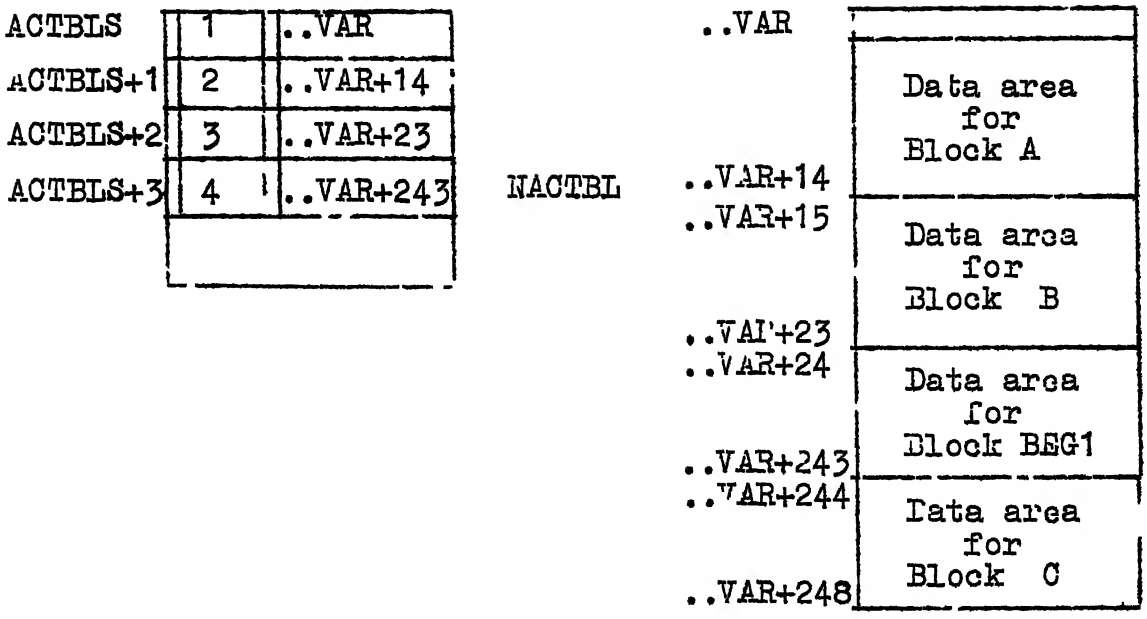
NACTBL = 4 NVARKB = 210

STPTKB = ..VAR+243

index '1' = complement of (..VAR+243)

index '2' = complement of (..VAR+23)

and the two stacks will look like as follows:



CHAPTER V

RUNTIME ROUTINES

.RTRTN This is one of main runtime routines which does the followings, depending upon the type of calling:

(1) It loads the block

(2) It erases the entry of current block from active block stack.

(3) It erases the entry of blocks upto the block mentioned by calling sequence.

(4) It loads the current block as well as checks the mode and type of arguments.

(5) It sends back the starting entry point of a block in Accumulator after fetching it from active block stack.

Calling Sequence of the Routine:

Routine may be called in one of the following ways:

(1) CLA = Number

TSL .RTRTN

where Number = IBLNO (internal block number)*2**18

+ no.of locations needed in the block

i.e. contants of AC are:

IBLNO	0	no.of loc.

The decrement portion of AC denotes the internal block number and the address portion contains the number of variables (locations) needed for this block.

Function. In this case .RTRTN loads the current block in active block stack and sets the pointers NACTBL, NVARKB, STPTKB as well as index 1 and index 2. It also allocates memory locations needed for this block.

(2) CLA = Number

TSL .RTRTN

where number is such that the content of AC is as follows:

	IBLNO	4	No. of Loc.

The only change in this type of calling with respect to the first type of calling is that TYPE = 4 i.e. $C(AC)_{18-20}$ is 4.

Function: In this case it is thought that this routine has been called from the beginning of either a parametric procedure block or from a functional block. In such a case it loads the current active block as well as compares for the proper mode and type between actual and formal parameters.

(3) CLA =2

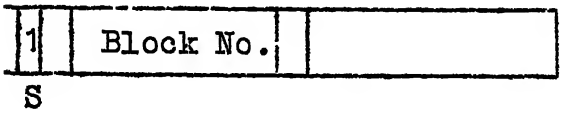
TSL .RTRTN

Function: In this case it is understood that the end of the current block has come (either due to the actual END statement or due to conditional or unconditional transfer). Hence the routine erases the entries for the current block from

block stack and the pointer in the variable stack is moved back to the block which is now active.

(4) CLS =Number
TSL .RTRTN

where the 'Number' is such that the C(AC) looks like:



Only the decrement portion gives the information to the routine. Address portion of the Accumulator is of no importance hence it can be used for other purposes.

Function: The routine erases the entry from the active block stack upto the point where the block mentioned in decrement portion of AC is found in the active block stack.

(5) CLA =3
LDQ =Number
TSL .RTRTN

Here 'Number' denotes the block number, the starting entry point of which (in active block stack) is needed.

Function: The routine compares the block number sent in the MQ register with the blocks filled in active block stack. If it matches, the corresponding starting entry point is taken from the active block stack and put in the accumulator. This is useful in putting the entries in the variable stack for the global identifiers.

..FNCH This is a small segment of .PTRTN routine and has an entry point in this routine. Before entering into this segment, it is understood that the control has been transferred from functional procedure. It checks for the valid reference of the function and sends the mode of the function procedure in runtime temporary storage.

..MDCH This routine is called by the following instructions:

```
TSX    ..MDCH,4
PZE    m,,tsp
```

where 'm' - denotes the mode of one operand

'tsp' - i.e. temporary storage pointer which denotes the location where the mode of second operand is filled.

Function: This routine compares the two modes and if they match, control is returned to the calling point otherwise error message is given. Such type of mode checking occurs in case the expression is of the form .

⟨identifier⟩ ⟨operator⟩ ⟨function⟩

or function operator identifier

..MDCH routine can also be called by the following instructions:

```
TSX    ..MDCH,4
MZE    tsp1,,tsp2
```

where 'tsp' - temporary storage point.

In this case modes are considered to be filled in the temporary storages mentioned in the decrement and address portion of the next location from the calling point (i.e. the location where the instruction is MZE tsp1,,tsp2). Such type of mode checking arises when the expression is of the form:

<function> <operator> <function>

RUNTIME ROUTINES

for subscripted variables (Array names)

Routines: .SUBR1, .SUBR2, .SUBR3

Whenever an identifier, say NAME, is declared as an array name, the declarative information (i.e. internal relative position number 'irpn' of the first element of the array and the upper limit of the subscript(s)) is stored as a part of the object code which will be referred to as .Vn, where 'n' is the internal number given to the array name.

Storing of declarative information has the following distinct uses by the object programme:

(a) Wherever 'NAME' is used (in arithmetic statements, I/O statements, etc.) it checks that the actual subscripts lie within the bounds specified.

(b) It calculates the absolute core address of the array element specified by the given subscripts.

Since .Vn is not a part of the executable object code at the point where it is generated, a transfer instruction is placed immediately before it to ensure that it is not executed at object time.

The object code generated for the array name 'NAME' depends on the number of subscripts in the array and is as follows:

```
.Vn     SXA     ..IDX2,2
        TSX     .SUBPm,2
        PZE     irpn
        PZE     P
        PZE     Q  only for two dimensions
        PZE     R  only for three dimensions
```

.SUBRm is one of the following routines depending upon the number of subscripts.

i) .SUBR1 for single subscripted.

ii) .SUBR2 for double subscripted.

iii) .SUBR3 for triple subscripted.

'irpn' is the internal relative position number of the first element of the array.

During compilation, whenever 'NAME' appears with subscripts, e.g. NAME(I,J,K), the following coding is generated:

```
        TSX     Vn,4
        PZE     I
        PZE     J
        PZE     K
        PZE     DADRES
```

where 'DADRES' is the desired address where the absolute address of the array element is to be put.

If the subscripted name is referred to as the global identifier, the following coding is generated:

```
        TSX     .Vn,4
        PZE     I
        PZE     J
        PZE     K
        MZE     DADRES,,irpn
```

where 'irpn' denotes the internal relative position number of the array name in this block.

In all the cases index '2' contains the complement of address of (.Vn+1) while index'4' contains the complement of the address of calling point.

The calculation of the absolute address of an element of the array name is based on the algorithm:

address of NAME(I,J,K) = address of NAME(1,1,1)

+ (I-1) + (J-1)*P + (K-1)*P*Q

Example:

```
A..PROCEDURE OPTIONS (MAIN) ,.
   DECLARE (M,N1(5),N2(2,3),N3(4,5,6))FIXED ,.
   M = 2 ,.
   N1(2) = N2(M,3) + N3(M,5,M) ,.
   ...   ...   . .
```

Coding of the above statements will be as follows:

```
        $IBMAP A
                TRA     .I0001
        .V0001  SXA     ..IDX2,2
```

```
        TSX    .SUBR1,2
        PZE    2
        PZE    5
.V0002  SXA    ..IDX2,2
        TSX    .SUBP2,2
        PZE    7
        PZE    2
        PZE    3
.V0003  SXA    ..IDX2,2
        TSX    .SUBR3,2
        PZE    13
        PZE    4
        PZE    5
        PZE    6
.I0001  BSS
        CLA    =2
        STO    1,1
        TSX    .V0001,4
        PZE    =2,,mode
        PZE    .T.+0
        TSX    .V0002,4
        PZE    1,1,mode        M
        PZE    =3,,mode
        PZE    .T.+1 contains address of N2(M,3)
        TSX    .V0003,4
        PZE    1,1,mode
        PZE    =5,,mode
```

```
PZE     1,1,mode
PZE     .T.+2   contains address of
                N3(M,5,M)
CLA*    .T.+1
ADD*    .T.+2
STO*    .T.+1
...     ...     ...
```

Instead of passing the subscripts by the instruction, PZE Arg, if it is passed by the instruction, ONE Arg, then the routines .SUBR1, .SUBR2 and .SUBR3 only check if the subscripts are within bounds. In this case they do not calculate the address of the element of the array.

.DORTN This is a runtime routine used for handling the modifications in control variables in a DO group during execution. Calling sequence of .DORTN is as follows.

```
TSX     .DORTN,4
CLA     c.v     control variable
STO     c.v
PZE     j       upper or lower bound of c.v
PZE     k       increment or decrement in c.v
                at each step.
```

.SUBPR This is a runtime routine, which transfers the the values of array elements from actual to formal parameter if both the parameters are array name and all elements are to be transferred. This routine is used for parametric procedure and function procedure.

.SBRST This is a runtime routine, which transfers values from formal parameter to actual parameter, if both the parameters are array name and all elements of which are to be transferred. This routine is called only when a parametric procedure ends.

.STNDX This is a runtime routine, which, when called, stores the values of index registers. This is used only for I/O statements.

..ESET This is a routine (runtime) which, when called, restores the values of index registers. This is used only for I/O statements.

Relational Operator Routine:

There are six entry points in this routine:

(1) RO.EQ. (2) RO.NE. (3) RO.LT. (4) RO.LE
(5) RO.GT. (6) RO.GE.

These six entries are for relational operators .EQ., .NE., .LT., .LE., .GT. and .GE. respectively. .NL. and .NG. are equivalent to .GE. and .LE. respectively.

At each entry point, it checks if the condition is true or not. In case it is true, $C(AC)_{P,1-35}$ is filled by 777777777777 with sign bit as plus; if the condition is false, C(AC) = 0.

CONCLUSION

Like FORTRAN compiler, IITPL compiler is also an out-core compiler, except the Runtime routines, which are there, in the core, at the time of execution. The Runtime routines approximately take 900 memory locations. Besides this, the compiler takes the help of some FORTRAN routines (namely I/O routines, EXP1 ...) which also will occupy some memory space but the memory, occupied by these routines are programme dependent. Only those routines will be in the core which are required by the programme, otherwise they will remain outside.

The compiler output is in MAP (Assembly language of IBM 7044), hence the assembler and its IOCS occupy round about 6000 memory locations. So, out of total 32768 memory locations, approximately 25000 memory locations are free for the object programme.

Since the compiler is an out-core type, its symbol table is so designed that it causes the compiler to take the whole of memory. If some addition is to be done in the compiler, the size of the symbol table (which is at present 4000) can always be reduced with a slight change in the system.

All the three sections, Lexical, Pass I & Pass II, and Runtime routines, have been tested separately and successfully. Till the end, the programme, handling CALL & GOTO statements, in Pass II, could not be fully tested, hence all the three sections of the compiler were not combined.

APPENDIX I

Here an example is taken to illustrate the PASS I output of the source statement (LITPL).

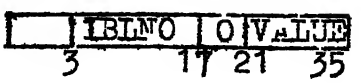
```
*PL/1
P1. PROCEDURE OPTIONS (ILLIN) ,.
    DECLARE (A,B,C,D,E,I) FIXED ,.
    DECLARE F(5,6,7) FIXED ,.
 M..A=A+B ,.
 L..IF(A.EQ.B) THEN IF(C.GT.2) THEN IF(A.NE.C)THEN A=0 ,.
    ELSE ,.
    ELSE IF(A.LT.C) THEN C=5 ,.
    ELSE A=C ,.
    CALL P2(A) ,.
    DO I=1, D WHILE A=3, 4 TO 7 BY 3 ,.
    A=A*(B+C/D**5)-8 ,.
    END/* THIS SHOWS THE END OF DO GROUP */ ,.
B1..BEGIN ,.
    DECLARE (A,M,N,P) FIXED ,.
    A=A+B ,.
    END B1 ,.
    GET EDIT (C,D,E) (F(6), X(3)) ,.
P2. PROCEDURE (G)/* SECOND BLOCK STARTS */ ,.
    DECLARE G FIXED ,.
    GOTO M,.
    RETURN ,.
    END P2 ,.
```

```
G.. FORMAT( F(6),X(1) ,.
    PUT EDIT(((F(A,B,C) DO A=D TO E
    BY I) DO B=3 TO E) DO C=I TO 6
    BY 3) (R(G)) ,.
    END P1 ,.
    *DATA
```

Coding

```
P1..PROCEDURE OPTIONS (MAIN) ,.
    DECLARE (A,B,C,D,E,I) FIXED ,.
    DECLARE F(5,6,7) FIXED ,.
```

```
    $IBMAP   P1
    P1       ERA    .IC001
    .V0001   SXA    ..IDX2,2
      -      TSX    .SUBR3,4
             PZE    7
             PZE    5
             PZE    6
             PZE    7
    .I0001   BSS
    000002   XXXXXX  A string which looks like
```




```
             TSL    .RTRTN
```

```
M..A=A+B,.
    M        CLA    1,1
             ADD    2,1
             STO    1,1
```

```
L..IF(A.EQ.B) THEN IF(..GT.2) THEN IF(A..E.C) THEN A=0,.

                L       CLA     1,1
                        SUB     2,1
                        TSX     RO.EQ.,4
                        TZE     .E0001
                        CLA     3,1
                        SUB     =2
                        TMX     RO.GT.,4
                        TZE     .E0002
                        CLA     1,1
                        SUB     3,1
                        TSX     RO.NE.,4
                        TZE     .E0003
                        CLA     =0
                        STO     1,1
                        TRA     .F0001
ELSE,.
ELSE IF(A.LT.8) THEN C=5,.
ELSE A=C ,.
ELSE ,.
                .E0003  TRA     .F0001
                .E0002  BSS
                        CLA     1,1
                        SUB     =8
                        TSX     RO.LT. ,4
```

```
                    TZE     .E0004
                    CLA     =5
                    STO     3,1
                    TRA     .F0001
.E0004              BSS
                    CLA     3,1
                    STO     1,1
                    TRA     .F0001
.E0001              TRA     .F0001
.F0001              BSS
```

CALL P2(A) ,.

```
000001  000002  P2X*00
000001  XXXXXX  -01000
```

where 'XXXXXX' is [illegible] characters [illegible].

```
DO I = 1,D WHILE A=3,4 TO 7 BY 3 ,.
A=A*(B+C/D**5)-8 ,.
END /* THIS SHOWS THE END OF DO GROUP */ ..
                    CLA     =1
                    STO     6,1
                    TSL     .D0001
                    CLA     4,1
                    STO     6,1
                    CLA     1,1
                    SUB     =3
                    TSX     RO.EQ.,4
                    TZE     *+2
```

```
        TSL     .D0001
        CLA     =4
        STO     6,1
        CLA     =7
        STO     D.0001+3
        CLA     2,1
        STO     D.0001+4
.W0001  TSL     .D0001
D.0001  TSX     .DORTN,4
        CLA     6,1
        STO     6,1
        PZE     0
        PZE     0
        TZE     E.0001
        TRA     .W0001
.D0001  TRA     *-*
```

* Coding of next statement starts here i.e. Assignment statement in this case.

```
        LDQ     4,1
        MPY     4,1
        STQ     .T.+0
        MPY     .T.+0
        MPY     4,1
        STQ     .T.+0
        LDQ     3,1
```

```
                PXD     ,0
                DVP     .T.+0
                LLS     35
                ADD     2,1
                LRS     35
                MPY     1,1
                LLS     35
                SUB     =8
                STO     1,1
        * Coding of END statement
                TRA     .D0001
         E.0001 BSS
B1..BEGIN ,.
    DECLARE (A,M,N,P) FIXED ,.
    A=A+B ,.
    END B1 ,.

        00000   XXXXX   A string which looks like

                        | | IBLNO | O | VALUE |
                        3       17  21      35

        B1      TRA     .I0002
        .I0002  BSS
                TSL     B.0002
                CLA     1,1
                ADD*    5,1
                STO     1,1
        00000;
```

```
              UT_    =2
              TSL    .RIRTN
              T?A    .B0002
B.0002        T_A    **
              ..L.   =Ø000002000005
              TSL    .R_TN
              CLA    =3
              LD_    =1
              TSL    .RT_T_
              ADD    =2
              STO    5,1
              TRA    B.0001
.B0002        TSG
GET EDIT(C,D,E) (F(5),X( )) ,.
              TSL    STTTX
              TSX    TSHIO.,4
              T O    TILO5
              PZE    nS
              TSL    ..S_F.
              TSL    HNLIO.
              STO    3.1
              TSL    HNLIO
              STO    4,1   .
              TSL    HNLIO.
              STO    5,1
              TSX    RTNIO.,4
              TRA    mE
nS            TSX    IOHTC.,4
              PZF    6
```

```
                    PZE     3
                    TRA     IOHEF.
nE      BSS                 where 'nE' is internal
                            name given by the
                            compiler, and 'm'=n+1
P2..PROC DUMP(C) ,.
    DEFINE 03 C 'CARD ,.
                    LDQ     .P0003
P2      NOP     *
                    LMJ     *-1,4
                    TRA     .I0003
.I0003  BSS
000003  XXXXXX              string counter as mentioned
                            earlier.
                    TSL     .PUTTN
                    TXI     *+2,,1
                    PZE     1
                    CLA     1,4
                    PLT     1,4
                    ANA     =Ø000003077777
                    ANA     =Ø000003277777
                    ORA     =Ø050000000000
                    SLW     *+1
                    CLA     **
                    STO     1,1
                    TSL     B.0003
GOTO M ,.
000000  000001  MBBBBB
```

```
RETURN ,.
                        TRA     A.0003
END P2 ,.
                    00000;
                A.0003 CLA     1,4
                       PLT     1,4
                       N       =Ø0000000077777
                       NA      =Ø000060277177
                       OR      =Ø050000000000
                       SLW     *+2
                       CLA     1,1
                       SLO     **
                       CLA     =2
                       ASL     .RTRTN
                       TRA     P2
               B.0003  TRA     **
                       TRA     B.0003
               .P0003  BSS
G..FORMAT(3 F(6),X(1)) ,.
                       TRA     nE
               C       .XT     3,2
                       TSX     IOHIC.,4
                       PZE     6
                       TSX     IOHXC.,4
                       PZE     1
                       TRA     IOHEF.
               nE      BSS
```

```
PUT EDIT(((F(A,B,C) DO A=D TO E BY I) DC B=3 TO E) DO C=I TO 6
                                    BY 3) (R(G)) ,.

                TSL     STNDX.
                TSX     STHIO.,4
                TWO     FIL06.
                PZE     2S
                TSL     RESET.
                LDQ     6,1
                STQ     3,1
.S0002          BSS
                LDQ     =3
                STQ     2,1
                CLA     5,1
                PAX     0,4
                SXD     .S0003,4
.S0004          BSS
                LDQ     4,1
                STQ     1,1
                CLA     5,1
                PAX     0,4
                SXD     .S0005,4
                CLA     6,1
                PAX     ,4
                SXD     .T0003+2,
                LDQ     3,1
                VLM     =983040,,1
```

```
        ALS    15
        LDQ    2,1
        VLA    =16384,,15
        AD     1,1
        SUB    ..IDX1
        PAI    ,2
        CLA    6,1
        PAX    ,4
        SXD    .S0001,4
.S0006  AS
        PAX    .V0001,1
        4      1,1
               ,1
        ON     ,1
        C      -29,
        ST     TITLE.
.NC     TX     +1    ,
.L0003  CL     1,1
        PAX    0,4
        TXI    +1,4,
        PXA    0,4
        STO    1,1
.S0005  TXL    .S0006,4,**
.T0002  CLA    2,1
        PAX    0,4
        TXI    *+1,4,1
        PXA    0,4
```

```
                    STO     2,1
             .S0003 TXL     .S0004,4,**
             .T0001 CLA     3,1
                    PAX     0,4
                    TXI     *+1,4,3
                    PXA     0,4
                    TXL     .S0002,4,6
                    TSX     RTNIO.,4
                    TX.     ..IDX2,2
             2S     TQU     G
END P1 ,.           GOGO;
                    ORA     S.JXIT
                    ENTRY   ..VAR
                    .XMAIN  ..IDX2
                    EXTER.  .RORTN
                    EXTER.  .RTRTN
                    EXTERN  .SSUBR3
                    EXTERN  .DORTN
             ..VAR  BSS     223
             .T.    BSS     1
                    END     P1
             $ENTRY
```

Note:

.SUBRm - This is the runtime routine for 'm' subscripted variable. It checks whether the subscripts exceeds its upper limit or not. If any one of the 'm' subscripts exceeds its upper limit, it gives error in execution time.

.RORTN - This is the relational operator runtime routine which sends zero in AC if the condition is false otherwise it puts 777777777777 in AC.

.RTRTN - This routine does the following:

i) if C(AC) is greater than 3, then it assumes that contents of Accumulator is in the following way:

Block No.	Type	No.of variables needed

If Type = 1 - then it loads the current block in the active block stack (ACTBLS) and moves the pointer (Index1) correspondingly.

= 4 - It assumes that current block is a parametric procedure block or functional procedure block. It checks the modes of the arguments and loads the current block.

ii) If the C(AC)=3 - it assumes that block no. has been sent in MQ. It then takes out the starting pointer in the variable stack (..VAR) for this block and puts it in AC and returns to the calling point.

iii) If the C(AC) = 2 - it erases the current block entry from ACTBLS (Active Block Stack).

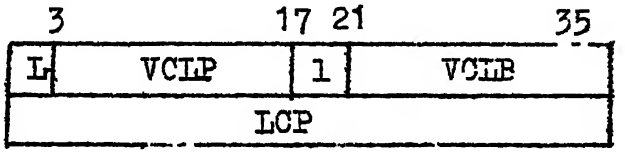
.DORTN - This routine checks whether the control variable has reached its limit value or not. If not it sends'1' in AC otherwise puts zero in AC and returns.

..IDX2 - This saves the content of index2.

APPENDIX II

ICALL Table:

In PASS I, when any procedure is called from any block; level and the symbol table address of the "Called Procedure" and that of 'Calling Block" is kept in a pair of words of ICALL table as shown below:



Where

L - Level of "Called procedure".

l - Level of "Calling block".

VCLP - Symbol table address of 'Called procedure".

VCLB - Symbol table address of "Calling block".

LCP - Label name of 'Called procedure".

It is not always possible to find the "Called procedure" in symbol table, in that case $C(\text{first word})_{S-17}$ is filled with zero. When a PROCEDURE statement is encounter d in PASS I, it is checked whether the name of the new procedure appears any where in the ICALL table undefined. If yes then L and VCLP is filled at that time.

Before filling information in the ICALL table, following things are kept in mind:

i) Repetition is avoided.

ii) (a) If "called procedure" is already in symbol table

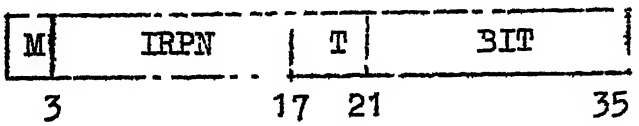
the following condition is to be satisfied:

L-1 = 0 or 1

(b) If "called procedure' has not come atall before the appearance of CALL statement, the validity of above condition is checked when PROCEDURE statement with the label of 'Called procedure" appears.

One hundred locations are reserved for ICALL table and the variable "NOCALL" is used as pointer of ICALL table.

CALL Argument Characteristic Word



where IRPN = Internal position number of the variable or temporary (when the argument is expression).

BIT = Number of bits required in the case of bit string and character string, otherwise 0.

T = 0 simple variable
= 1 Single subscripted
= 2 Double subscripted
= 3 Triple subscripted
= 4 Temporary (in case of expression)
= 5 Constant
= 6 Functional argument

When T=5 'IRPN' points the number of words following the characteristic word which store the constant.

M = 0 Label variable

= 1 Simple and subscripted variable

= 2 Bit string variable

= 3 Character string variable

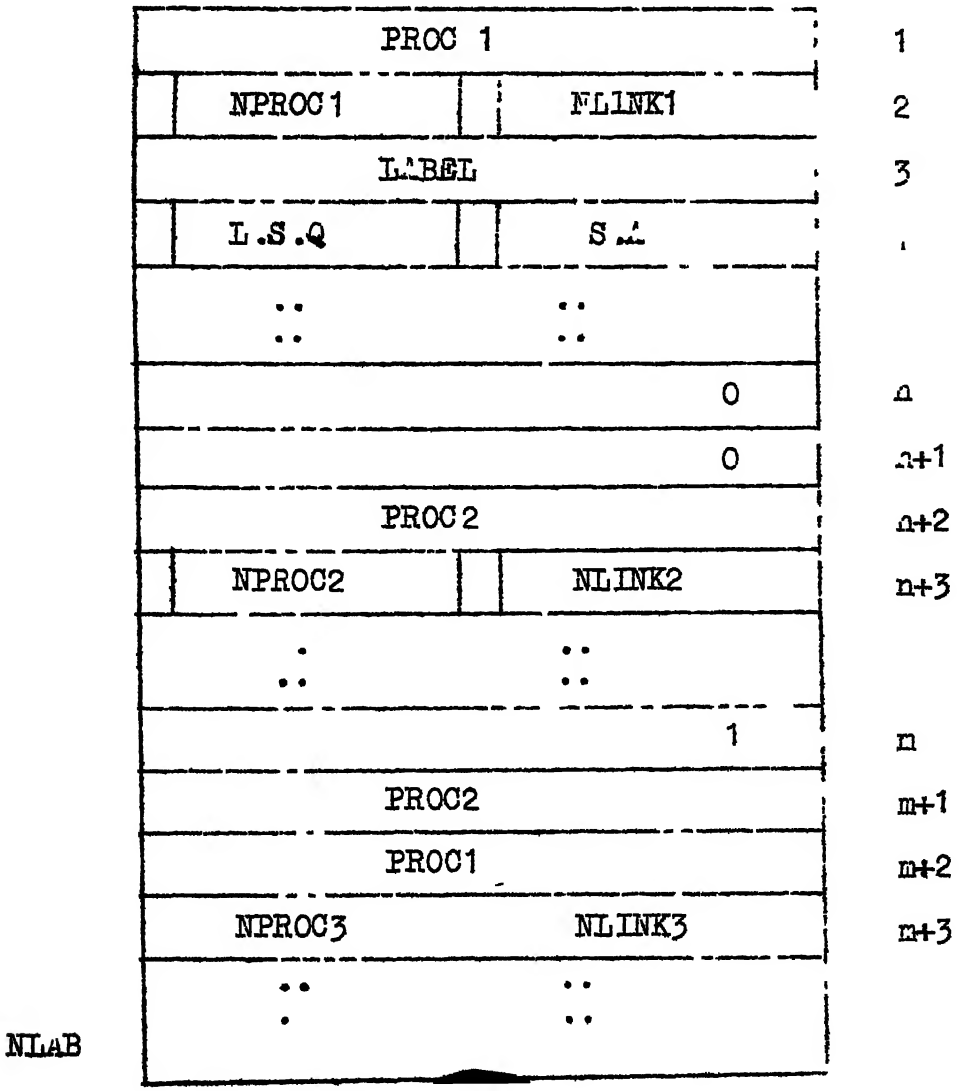
= 5 External fixed variable

= 6 External bit variable

= 7 External character variable

GOTO Table

GOTO table is is the table of unfound labels of procedures. All unfound labels of any particular procedure are kept as an element of the string, whose HEADER keeps the name of the procedure and information about the next link of the string.



where NPROC - Table address of the first element of the string, which starts just after this string section is over.

NLINK - Table address of the HEADER of the next link of the very PROCEDURE string.

SA - Symbol table address of the label.

L.S.Q - Level Sequence - number

Before storing the unfound label and its characteristics, it is always checked whether it is already an element of the string of unfound labels of the procedure.

If END statement corresponding to any procedure is encountered and if this procedure is having a string of unfound labels, then it is permanently closed at string 1 and procedure's label in the last two consecutive locations of the string of the GOTO table and running procedure is rubbed off from IGBLK table.

If any procedure starts before permanent end of the last running procedure, then the GOTO table string of the previous procedure is temporary closed with 0 and 0 in next two free locations and then HEADER for new string is kept thereafter.

As shown in example above:

NPROC1 = Table address of PROC2 i.e. n+2.

NLINK1 = Address of next link of PROC1 i.e. n+2

NPROC2 = Table address of next procedure(i.e. of PROC1) i.e. m+2.

NLINK2 = 0

IGBLK Table:

This is the procedure block table used for handling the GOTO table. Each time PROCEDURE statement is encountered, it is entered in the IGBLK table. Each entry in IGBLK requres two words of IBM 7044 which consists the following:

Procedure name
SPTGO

where 'SPTGO' is the starting pointer in the GOTO table wherefrom any external label needed for this procedure block is put. The first entry in the GOTO table for any procedure block is the procedure name itself and the string of unfound labels, needed by that particular procedure, are put thereafter. If there is no global label needed by this procedure block, SPTGO is set to zero.

'NPB' is the pointer for handling IGBLK table. When an END statement is encountered the 'NPB' is moved up.

THE SYMBOL TABLE

During the Pass 1 of the compilation of a source programme, Symbol table entries are filled. A Symbol table entry consists of four consecutive words packed with information concerning one of the following entities which occur in the programme segment (External Procedure) being compiled:

(1) Variable name

  (i) Non subscripted

  (ii) Single subscripted

  (iii) Double subscripted

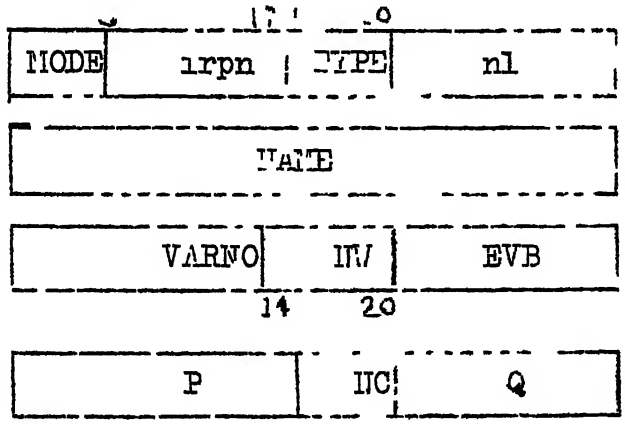
  (iv) Triple subscripted

(2) Procedure name

(3) Label name

Symbol Table Entry for

(a) Variable name:



nl = pointer to next item with the same hash address if there is any. Else nl = 0.

TYPE = 0 for non subscripted variables

= 1 for single subscripted variables.

= 2 for double subscripted variables.

= 3 for triple subscripted variables.

= 4 for Procedure name.

= 5 for label name.

EVB: This is the Symbol table address of the block under which this name (variable, procedure or label) has come. EVB=0 for the External Procedure name.

MODE = 1 for attribute FIXED.

= 2 for attribute BIT.

= 3 for attribute CHARACTER.

irpn = Internal relative position number of the variable in the block under which this variable name has been declared.

VARNO= Internal sequence number of the subscripted variable.

= 0 for non subscripted variable.

NW = Number of words needed by the variable.

P = Upper limit of the first subscript.

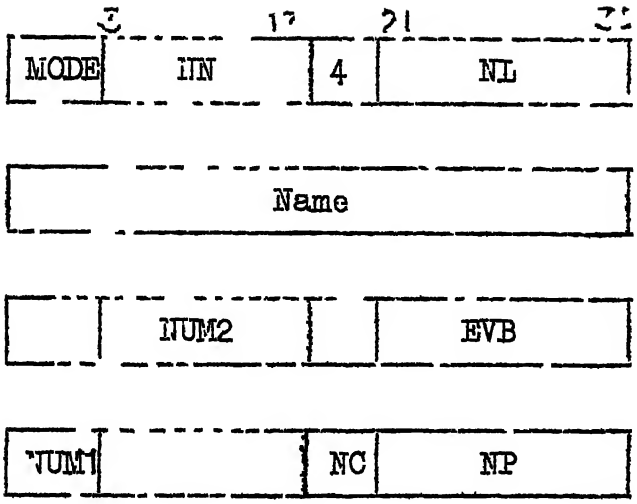
= 0 for non subscripted variable.

Q = Upper limit of the second subscript.

= 0 for single and non subscripted variable.

NC = Number of characters in the variable name itself, e.g. if the variable is 'ABD' then NC=3.

(b) Procedure name:



MODE = 1 for simple procedure without any formal parameter.

= 2 for parametric procedure.

= 3 for functional procedure with attribute FIXED.

= 4 for functional procedure with attribute BIT.

= 5 for functional procedure with attribute CHARACTER.

NN = Number of bits needed for a BIT or CHARACTOR attribute of Built in function or Home made function.

= 0 otherwise.

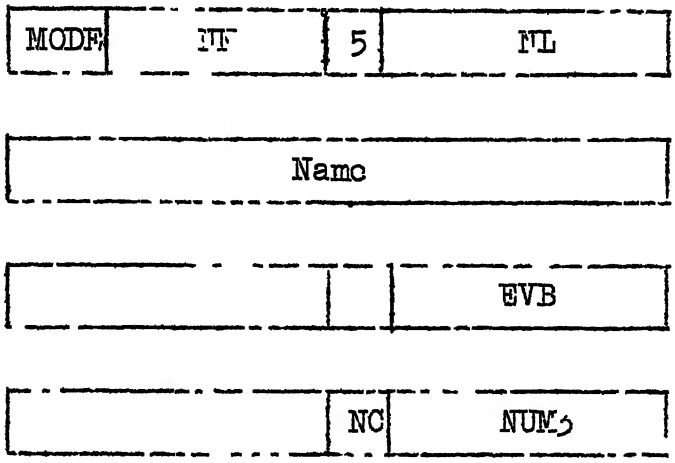
NUM2 = Level of the block.

NP = No. of formal parameters in the procedure if any.

= 0 otherwise.

(c) Label name:

Label name includes DO name and BEGIN name also.



MODE = 0 if this label is under Procedure block.

= 1 if it is under Begin block.

= 2 if it is under DO block.

NN = Level sequence number.

NUM3 = Internal DO number if this label is under DO block.

APPENDIX III

Here an example is taken to illustrate the coding of the source statement (IITPL).

```
^PL/1
P1..PROCEDURE OPTIONS (MAIN) ,.
    DECLARE (A,B,C,D,E,I) FIXED ,.
    DECLARE F(5,6,7) FIXED ,.
 M..A=A+B ,.
 L..IF(A.EQ.B) THEN IF(C.GT.2) THEN IF(A.NE.C)THEN A=0,.
    ELSE ,.
    ELSE IF(A.LT.8) THEN C=5 ,.
    ELSE A=C ,.
    CALL P2(A) ,.
    DO I=1, D WHILE A=3, 4 TO 7 BY B ,.
    A=A*(B+C/D**5)-8 ,.
    END/* THIS SHOWS THE END OF DO GROUP */ ,.
    GET EDIT (C,D,E) (F (6), X(3)) ,.
B1..BEGIN ,.
    DECLARE (A,M,N,P) FIXED ,.
    A = A+B ,.
    END B1 ,.
P2..PROCEDURE (G) /* SECOND BLOCK STARTS */ ,.
    DECLARE G FIXED ,.
    GOTO M,.
    RETURN ,.
    END P2 ,.
```

```
G..FORMAT(3 F(6),X(1)) ,.
   PUT EDIT (((F(A,B,C) DO A=D TO E
   BY I) DO B=3 TO E) DO C=I TO 6
   BY 3) (R(G)) ,.
   END P1 ,.
   *DATA
```

Coding (Final)

```
$IBMAP P1
P1      TRA     .I0001
.V0001  SXA     ..IDX2,2
        TSX     .SUBR3,4
        PZE     7
        PZE     5
        PZE     6
        PZE     7
.I0001  BSS
        CLA     =Ø000001000330
        TSL     .RTRTN
M       CLA     1,1
        ADD     2,1
        STO     1,1
```

```
L..IF(A.EQ.B) THEN IF(C.GT.2) THEN IF(A.NE.C) THEN A=0,.

                L       CLA     1,1
                        SUB     2,1
                        TSX     RO.EQ.,4
                        TZE     .E0001
                        CLA     3,1
                        SUB     =2
                        TSX     RO.GT.,4
                        TZE     .E0002
                        CLA     1,1
                        SUB     3,1
                        TSX     RO.NE.,4
                        TZE     .E0003
                        CLA     =0
                        STO     1,1
                        TRA     .F0001
ELSE,.
ELSE IF(A.LT.8) THEN C=5,.
ELSE A=C ,.
ELSE ,.
                .E0003  TRA     .F0001
                .E0002  BSS
                        CLA     1,1
                        SUB     =8
                        TSX     RO.LT.,4
```

```
                    TZE     .E0004
                    CLA     =5
                    STO     3,1
                    TRA     .F0001
              .E0004 BSS
                    CLA     3,1
                    STO     1,1
                    TRA     .F0001
              .E0001 TRA    .F0001
              .F0001 BSS

CALL P2(A),.        TSL     P2
                    TXI     *+3,,1
                    PZE     1,3,mode
                    TRA     M

DO I = 1,D WHILE A=3,4 TO 7 BY B ,.
A = A**(B+C/D**5)-8 ,.
END /* THIS SHOWS THE END OF DO GROUP */ ,.
                    CLA     =1
                    STO     6,1
                    TSL     .D0001
                    CLA     4,1
                    STO     6,1
                    CLA     1,1
                    SUB     =3
                    TSX     R0.EQ.,4
                    TZE     *+2
```

```
        TSL     .D0001
        CLA     =4
        STO     6,1
        CLA     =7
        STO     D.0001+3
        CLA     2,1
        STO     D.0001+4
.W0001  TSL     .D0001
D.0001  TSX     .DORTN,4
        CLA     6,1
        STO     6,1
        PZE     0
        PZE     0
        TZE     E.0001
        TRA     .W0001
D0001   TRA     *-*
```

* Coding of next statement starts here i.e. Assignment statement in this case.

```
        LDQ     4,1
        MPY     4,1
        STQ     .T.+0
        MPY     .T.+0
        MPY     4,1
        STQ     .T.+0
        LDQ     3,1
```

```
                    PXD     ,0
                    DVP     .T.+0
                    LLS     35
                    ADD     2.1
                    LRS     35
                    MPY     1,1
                    LLS     35
                    SUB     =8
                    STO     1,1
                    TRA     .D0001
          E.0001    BSS
```

Coding for all the rest statements:

```
                    TSL     STNDX.
                    TSX     TSHIO.,4
                    TWO     FIL05.
                    PZE     nS
                    TSL     RESET.
                    TSL     HNLIO.
                    STO     3,1
                    TSL     HNLIO.
                    STO     4,1
                    TSL     HNLIO
                    STO     5,1
                    TSX     RTNIO.,4
                    TRA     mE
          nS        TSX     IOHIC.,4
                    PZE     6
                    TSX     IOHXC.,4
                    PZE     3
                    TRA     IOHEF.
          mE        BSS
```

```
B1      TRA     .I0002
.I0002  BSS
        TSL     B.0002
        CLA     1,1
        ADD*    5,1
        STO     1,1
        CLA     =2
        TSL     .RTRTN
        TRA     .B0002
B.0002  TRA     **
        CL      =Ø000002000005
        TSL     .RTRTN
        CL      =3
        LDQ     =1
        TSL     .RTRTN
        ADD     =2
        STO     5,1
        TRA     B.0002
.B0002  BSS
        TRA     .P0003
P2      TRA     **
        LAC     *-1,4
        TRA     .I0003
.I0003  BSS
        CLA     =Ø000003400001
        TSL     .RTRTN
```

```
                TXI     *+2,,1
                PZE     1
                CLA     1,4
                PLT     1,4
                ANA     =Ø000000077777
                ANA     =Ø000060277777
                ORA     =Ø050000000000
                SLW     *+1
                CLA     **
                STO     1,1
                TSL     B.0003
                TRA     .L0001
                TRA     A.0003
                TRA     .R0001
.L0001          CLA     =2
                PSL     .RTRTN
                LXA     P2,4
                SXA     *+1,4
                LXA     **,4
                TIX     *+1,4,1
                SXA     *+1,4
                TRA     **
.R0001          BSS
A.0003          LAC     P2,4
                CLA     1,4
                PLT     1,4
                ANA     =Ø000000077777
                ANA     =Ø000060277777
                ORA     =Ø05Ø000000000
```

```
                SLW     *+2
                CLA     1,1
                STO     *'
                CLA     =2
                TSL     .RTRTN
                TRA     P2
B.0003          TRA     **
                TRA     B.0003
.P0003          BSS
                TRA     nE
G               AXT     3,2
                TSX     IOHIC.,4
                PZE     6
                TSX     IOHXC.,4
                PZE     1
                TRA     IOHEF.
nE              BSS
                TSL     STNDX.
                TSX     STHIO.,4
                TWO     FIL06.
                PZE     2S
                TSL     RESET
                LDQ     6,1
                STQ     3,1
.S0002          BSS
                LDQ     =3
                STQ     2,1
```

```
        CLA     5,1
        PAX     0,4
        SXD     .S0003,4
.S0004  BSS
        LDQ     4,1
        STQ     1,1
        CLA     5,1
        PAX     0,4
        SXD     .S0005,4
        CLA     6,1
        PAX     ,4
        SXD     .T0003+2,4
        LDQ     3,1
        VLM     =983040,,15
        ALS     15
        LDQ     2,1
        VMA     =163840,,15
        ADD     1,1
        SUB     ..IDX1
        PAC     ,2
        CLA     6,1
        PAX     ,4
        SXD     .N0001,4
.S0006  BSS
        TSX     .V0001,4
        ONE     1,1
        ONE     2,1
        ONE     3,1
        CLA     -29,2
```

```
        TSL     HNLIO.
.N0001  TXI     *+1,2,**
.T0003  CLA     1,1
        PAX     0,4
        TXI     *+1,4,**
        PXA     0,4
        STO     1,1
.S0005  TXL     .S0006,4,**
.T0002  CLA     2,1
        PAX     0,4
        TXI     *+1,4,1
        PXA     0,4
        STO     2,1
.S0003  TXL     .S0004,4,**
.T0001  CLA     3,1
        PAX     0,4
        TXI     *+1,4,3
        PXA     0,4
        TXL     .S0002,4,6
        TSX     RTNIO.,4
        LXA     ..IDX2,2
2S      EQU     G
        TRA     S.JXIT
        ENTRY   ..VAR
        EXTERN  ..IDX2
```

```
        EXTERN  .RORTN
        EXTERN  .RTRTN
        EXTERN  .SUBR3
        EXTERN  .DORTN
..VAR   BSS     223
.T.     BSS     1
        END     P1
$ENTRY
```

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